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Residents' Annoyance Responses to Aircraft Noise Events

Thomas K. Dempsey
and David G. Stephens
Langley Research Center
Hampton, Virginia

James M. Fields
and Kevin P. Shepherd
The Bionetics Corporation
Hampton, Virginia

National Aeronautics
and Space Administration

Scientific and Technical Information Branch

SUMMARY

A study was conducted in the vicinity of Salt Lake City International Airport in which community residents reported their annoyance with individual aircraft flyovers during rating sessions conducted in their homes. Annoyance ratings were obtained at different times of the day. Aircraft noise levels were measured, and other characteristics of the aircraft were noted by trained observers.

Metrics commonly used for assessing aircraft noise were compared, but none performed significantly better than A-weighted sound pressure level. A significant difference was found between the ratings of commercial jet aircraft and general aviation propeller aircraft, with the latter being judged less annoying. After the effects of noise level were accounted for, no significant differences were found between the ratings of landings and take-offs.

Aircraft noise annoyance reactions are stronger under low outdoor ambient noise conditions than under high outdoor ambient noise conditions. This relationship is consistent with the theory that reduced nighttime ambient levels may result in more negative reactions to aircraft noise at night than during the day. After controlling for ambient noise in a multiple regression analysis, no significant differences were found between the ratings of single events obtained during the three time periods: morning, afternoon, and evening.

The combination of field and laboratory study techniques used in this study is most suitable for examining reactions to noise when residents may associate important nonacoustical attributes (e.g., type of aircraft or flight maneuver) with the acoustical events.

INTRODUCTION

The effective control of aircraft noise in communities near airports, whether accomplished through source noise reduction, operational procedures, and/or land use planning, requires an understanding of the relationship between the amount of noise exposure ("dose") and the "response" of the community residents. Such a relationship may be influenced by many factors, including characteristics of the aircraft events (e.g., aircraft type, mode of operation, and number of events), characteristics of the airport community (e.g., ambient noise), and characteristics of individual residents (e.g., sensitivity to noise and attitudes toward airport).

Two classical approaches have been used to study human response to aircraft noise. Laboratory studies have examined the relationship between annoyance and the acoustical characteristics of individual flyovers. This work led to the development of noise metrics (e.g., effective perceived noise level (EPNL)) which represent, with reasonable accuracy, the effects of frequency content and duration of jet aircraft flyover noise on human response. Laboratory studies have the major advantage of allowing the experimenter to control the content and mix of the aircraft noises. However, the validity of their findings for a community setting can be questioned.

In contrast, surveys have examined community response to long-term aircraft noise exposure. In this approach, each community resident provides a judgment about a single real aircraft noise environment. However, difficulties arise because the noise environment is often poorly quantified (the long-term, year-long noise environment cannot be directly measured), and, more importantly, the noise environments are not subject to manipulation. As a result, many characteristics of the noise environments are so highly correlated with each other that their independent effects on annoyance cannot be determined with any degree of precision.

The present study uses a new methodology which, in effect, is a combination of the techniques used in laboratory and community studies. The basic approach is to bring together small groups of airport community residents in one of their homes and have them make annoyance ratings of a large number of aircraft flyovers which occur during the rating period. In this way, it was hoped to gain information on metrics, differences between types of aircraft, differences between modes of operation (take-off or landing), effects of time-of-day, and effects of ambient noise. After the aircraft rating session, a questionnaire concerning annoyance to the long-term noise environment at different times of the day was administered to the study participants. The questionnaire was also used to gather standard demographic information.

SYMBOLS AND ABBREVIATIONS

B	regression coefficient (slope)
B_L	regression coefficient for noise level in multiple regression equation
B_m	regression coefficient for miscellaneous aircraft variable in multiple regression equation
B_p	regression coefficient for propeller aircraft variable in multiple regression equation
B_v	regression coefficient for aircraft, community, or personal variable in multiple regression equation
L_A	A-weighted sound pressure level (ref. 1), dB
L_B	B-weighted sound pressure level (ref. 1), dB
L_C	C-weighted sound pressure level (ref. 1), dB
L_D	D-weighted sound pressure level (ref. 1), dB
L_{dn}	day-night average sound pressure level (ref. 1), dB
L_E	E-weighted sound pressure level (ref. 1), dB
L_{eq}	equivalent continuous sound pressure level; A-weighted sound energy level averaged over a specified period of time (ref. 1), dB
LL	loudness level (Stevens Mark VI procedure, ref. 3), dB
PL	perceived level (Stevens Mark VII procedure, ref. 2), dB

PNL	perceived noise level (ref. 1), dB
p	probability
SIL	speech interference level (ref. 1), dB
SPL	unweighted sound pressure level, dB
σ	standard deviation
σ^2	variance

OVERVIEW OF DATA ACQUISITION

Simultaneous noise measurements and annoyance ratings were obtained for a total of 293 aircraft flyovers which were divided among the 25 rating sessions. The 293 flyovers generated a total of 1164 aircraft noise ratings from the 100 participants who were divided among the 25 rating sessions. Each session was conducted in a different house (three to six people per house). Each person participated in only 1 of the 25 sessions. Other acoustical and nonacoustical information gathered during the rating period included aircraft type, aircraft mode of operation (take-off or landing), time of day, ambient noise, participants' hearing acuity, and demographic characteristics of the participants.

The study was conducted during the week of November 17, 1980. The time of day of the 25 rating sessions was systematically varied in the study design. An equal number of sessions were scheduled during the morning (9 a.m. to 12 noon), afternoon (3 p.m. to 5 p.m.), and evening (8 p.m. to 10 p.m.).

AIRPORT COMMUNITY

The study was carried out in a small residential community located south of Salt Lake City International Airport (fig. 1). This community of approximately 55 houses (200 to 250 residents) is located primarily within the $L_{dn} = 70$ dB contour. The airport handles approximately 250 commercial, 450 general aviation, and 30 military operations a day. Of the three runways (34L/16R, 34R/16L, and 32), the first is used for commercial, military, and many general aviation operations; the second is used mainly for the remaining military operations; and the third is limited to general aviation movements.

SELECTION OF PARTICIPANTS

Every resident (18 years of age or older) in the selected community was eligible for participation in the study. The three procedures used to maximize the number of participants were, in chronological order, (1) a letter of invitation, (2) contact by telephone, and (3) on-site visitations. Each resident was thus given an opportunity to participate in the study.

A house was selected as a study site if a minimum of three of the residents at that house and/or close neighbors volunteered to participate. The 101 volunteer residents, one of whom was not included due to extreme hearing loss, were assigned to 25 houses. The residents were paid a nominal fee for their participation.

STUDY PROCEDURE

The data acquisition team spent a total of 2 1/2 hours at each study site. In chronological order, this period included time for (1) completion of consent forms (appendix A), (2) placement and calibration of indoor and outdoor noise measurement equipment, (3) arrangement of seats around one of the indoor noise measurement locations, (4) distribution of the annoyance recording device and instruction in its use, (5) 1 hour of rating aircraft flyover noise, (6) completion of questionnaires, and (7) posttest calibration of noise measurement equipment. Further details concerning the methods of data collection are presented in the following sections of this report.

Through the use of two data acquisition teams, six 1-hour rating periods could be scheduled per day. Despite some cancellations, 25 rating periods were completed within 4 1/2 days.

SUBJECTIVE DATA

Annoyance With Individual Flyovers

Participants recorded their noise annoyance ratings on the hand-held response panel shown in figure 2. The panel has nine push buttons representing an annoyance scale from 0 (not annoyed at all) to 8 (extremely annoyed). A small display located above the buttons indicates which button has been pushed. A reset button allows a participant to change his/her annoyance rating within 15 seconds of the initial response. The exact instructions given to the participants are contained in appendix B. The annoyance ratings were digitally coded and recorded on magnetic tape in a mobile instrumentation van located adjacent to the house.

Questionnaire

A questionnaire was completed by each participant after the rating session (appendix C). This self-administered questionnaire gathered data on demographic characteristics and responses to the long-term aircraft noise environment at different times of day.

AIRCRAFT DATA

Noise Measurement

A multichannel FM tape recorder located in a mobile instrumentation van simultaneously recorded indoor and outdoor aircraft acoustical data as well as the annoyance responses. The tape recorder operated continuously during each 1-hour rating period.

Recorded data included the following:

(1) Outdoor sound pressure levels. Two 0.5-in. (1.27-cm) condenser microphones, about 4 ft (1.2 m) from the ground surface, were placed adjacent to each other and in a position that was not acoustically shielded by the house (fig. 3). The gain

settings on the two microphone signal amplifiers were set 10 dB apart in order to maximize the signal-to-noise ratio and to minimize data lost due to instrumentation overload.

(2) Indoor sound pressure levels. Two 0.5-in. (1.27-cm) microphones were located about 4 ft (1.2 m) from the floor surface. One microphone was always placed in the rating room in the center of the participants (fig. 4) and the other in the center of a remote, unoccupied room, preferably with one wall directly impacted by aircraft noise.

(3) Microphone signal amplifier gain settings.

(4) Annoyance ratings from the response panels.

(5) Aircraft identification. A member of the data acquisition team located outside the house identified the aircraft. Information concerning the aircraft type and its mode of operation was digitally encoded and recorded.

(6) Voice annotation.

(7) Time code.

Aircraft Identification

A radar screen located in the airport control tower was used as the primary source (observers at the study sites were secondary sources) for identification of aircraft. The following information was recorded for each flyover: (1) aircraft type, (2) mode of operation (take-off or landing), (3) time of overflight, (4) runway used, and (5) flight number.

AUDIOGRAMS

Prior to the study, participants were routinely given a hearing test in a mobile van containing an audiometric booth. Pure-tone test frequencies were 500, 1000, 2000, 3000, 4000, and 6000 Hz. These data were collected in order to determine if the annoyance responses were influenced by the participants' hearing loss. One potential participant was excluded from the study because of obviously severe hearing loss.

OUTDOOR AMBIENT NOISE

Ambient noise data were collected out-of-doors during the part of the test session periods when aircraft were not audible. Measurements were made with a commercially available sound level analyzer and a 0.5-in. (1.27-cm) condenser microphone located about 4 ft (1.2 m) from the ground surface. The microphone was located about 6.5 ft (2 m) from the outside of the house, but not within noise shadows. An operator ensured that only nonaircraft noise data were processed. The sound level analyzer, which has a 60-dB dynamic range, provided direct analysis of the noise environment in terms of the distribution of L_A and L_{eq} levels. A minimum of two samples, each of 1000-seconds' duration, were used to characterize the noise environment during each 1-hour test period.

PRETESTS

The procedures were pretested before use in Salt Lake City. The pretests included (1) administration of the self-completion questionnaire to 96 local Virginia residents in a briefing room at NASA Langley Research Center (LaRC), (2) simulation of the community test environment with indoor and outdoor psychoacoustic facilities at LaRC, and (3) a trial in-home rating session in an airport community home near LaRC.

DATA REDUCTION

The recordings of the aircraft flyovers were analyzed into 0.5-second one-third-octave band spectra for calculating noise metrics including unweighted sound pressure level (SPL), A-weighted sound pressure level (L_A), perceived noise level (PNL), and D-weighted sound pressure level (L_D). Tone and duration corrections were computed using the FAR 36 (Federal Aviation Regulation 36) procedure (ref. 4). These data and the corresponding annoyance responses and questionnaire data were collated onto computer files.

FINDINGS

Dose-Response Relationship

The relationship between outdoor peak aircraft noise level (in A-weighted decibels) and response to the individual flyovers is summarized in figure 5. (Appendix D contains the count of the individual scores.) The means of the reactions are plotted for 5-dB increments. Figure 5 also includes the linear regression line which best fits the 1164 individual ratings of the flyovers. There is, of course, considerable variability in the individual responses. The standard deviation of the individual 9-point annoyance scale scores around the regression line is 2.05. Part of this variability in responses arises from factors which were measured in this study and are analyzed in the remainder of this report. Much of the variability in response cannot be traced to any of the measured variables; thus, this variability is treated as random "error" for the purpose of the analyses here.

These random "errors" are of at least three types: errors in an individual's response (e.g., not paying attention to aircraft flyover, pushing the wrong button, and being uncertain about how to express feelings on a numerical scale), differences between individuals (e.g., different sensitivities to noise and variations in other attitudes which affect feelings about aircraft), and unidentified differences between groups of participants (e.g., history of public relations with airport, consensus about noise based on neighborhood discussions, discussion which occurs during the rating period, and variation in the noise-reduction characteristics of the different houses). Inasmuch as these variations are present in all populations and they cannot be used in setting public policy, the chief interest is in obtaining good estimates of the mean of the responses. The precision of the estimate of the average response is indicated by the two curved lines in figure 5. These are the 95-percent confidence intervals for the prediction of the mean response at each noise level. These confidence intervals and all inductive statistics in this report are based on a sampling error computation technique (jackknife repeated replication) which takes into account the fact that both individuals and neighborhoods may differ in their responses (ref. 5).

The broad confidence intervals in figure 5 show that the dose-response relationship is not precisely defined with the data from this study. Reasons for the lack of precision are explored in the methodological assessment section of this report. This imprecision means that only variables with very strong effects can be examined in this study. Significance tests and other inductive statistics are used to identify reliable findings.

The relationship between annoyance and noise level in figure 5 is essentially linear over the 60- to 100-dB(A) range examined in the study. The relationship defined using cubic equations predicts virtually the same annoyance response (a difference of less than 0.06 annoyance score points) and does not significantly increase the proportion of variance explained by noise level ($p > 0.05$). The annoyance by noise level relationship remains linear when tone and duration corrections are introduced and when other frequency weightings are considered (PNL, L_D, and SPL).

Noise Metrics

Ten different noise metrics, including tone and duration corrections where appropriate, were examined. The correlation between annoyance and each of the metrics is given for both linear and quadratic equations in table I. Examination of the table shows that the differences between the correlation coefficients are generally small. None of the differences in table I are statistically significant ($p > 0.05$). The correlations observed for the widely used A-weighting are not exceeded by the more complex aircraft metric (PNL) or by the tone or duration correction procedures.

Time-of-Day Effects

Several approaches are followed here to estimate the effects of the time of day at which aircraft noise is heard. Conventional survey questions explored reactions to the long-term average noise environment. The ratings of individual aircraft during the testing session were then used to explore two possible explanations for time-of-day effects; the effect of ambient noise levels (levels are generally lower at night than at other times of day in residential areas) and the possibility of pure time-of-day differences such as circadian rhythm effects.

Rating of long-term noise environments.- In the post-rating-session questionnaire, participants rated their long-term aircraft noise annoyance for each hour of the day that they routinely spent at home (question 23, appendix C). In figure 6 annoyance during the evening hours is significantly greater than during the daytime ($p < 0.05$). This difference could, of course, simply reflect differences in aircraft noise exposure during a typical day. If the hourly average peak noise level from aircraft is assumed to be reasonably constant, any differences in noise exposure are simply due to the numbers of flyovers. Figure 7 presents the average number of scheduled operations for each hour of the day for weekdays and for the weekend. The obvious peak in the number of flyovers during the evening (9 p.m.) is the equivalent of about a 2- to 3-dB increase in L_{eq}, if the energy equivalent model implicit in L_{eq} is accepted. One possible explanation for the heightened evening reaction is thus the 2- to 3-dB increase in noise level. Two patterns in the data do, however, support the interpretation that heightened evening reaction is not simply explained by the high number of movements at 9 p.m.: (1) the number of aircraft movements from 4 p.m. to 7 p.m. does not exceed the highest movement levels at other periods of the day, but the reaction increases over that period, and (2) the sharp increase in number at 9 p.m. does not create a corresponding sharp increase in annoyance at 9 p.m. or even 8 p.m. or 10 p.m. No conclusions can be drawn concerning the relative impact of nighttime movements (12 p.m. to 6 a.m.) because of the lack of aircraft operations during that time period.

Outdoor ambient noise level.- Ratings of the individual flyovers at sites with different outdoor ambient noise levels provide a test of the hypothesis that time-of-day effects can be traced to lowered nighttime ambient noise levels. The hypothesis is that reactions to aircraft are heightened when there are lowered ambient noise levels. As a result it is theorized that any difference in day and evening reactions is simply a function of differences in ambient noise levels.

During each aircraft rating period, the outdoor ambient noise level was measured at the site. Ambient L_{eq} levels, excluding aircraft noise, ranged from 43 to 73 dB. The highest levels were obtained at sites near a railroad and at sites near a busy street with some heavy vehicle traffic. These higher ambient noise level sites thus also had the most variable ambient noise levels.

Figure 8 gives the average of the ratings of aircraft flyovers in three different ambient noise level groups. In general, ratings of aircraft noise annoyance increase as ambient levels decrease. The apparent interaction between ambient level effects and aircraft noise level effects (ambient noise does not appear to affect annoyance at the lowest aircraft noise levels) was found to not be statistically significant ($p > 0.05$). The curves in figure 8 show there is a great deal of variation in responses which has not been explained by either aircraft or ambient noise level. In order to take account of that variation and to represent the noise levels continuously instead of in the crude 10-dB groups of figure 8, a more detailed analysis is presented in table II.

Table II presents the basic data for the effects of community, aircraft, and personal variables on noise annoyance with individual aircraft flyovers. The statistics for the ambient noise level analysis serve to illustrate the information which is available for all variables.

In the ambient noise level row of table II, the first column shows that ambient noise level is coded in L_{eq}. The second column shows that 90 percent of the observations in the sample are between ambient L_{eq} values of 46 and 67 dB. The next five columns give the parameters from the multiple regression of the 9-point annoyance scale on aircraft noise level, aircraft type (partial regression coefficients for aircraft type represent deviations from the jet aircraft reactions), and the particular characteristic presented in the first column (in this case, ambient noise level). The standard error of each estimated partial regression coefficient is given immediately below in parentheses. The last three columns of the table present the estimated effects in terms of a more meaningful unit, the number of decibels of aircraft noise which would bring about an equivalent change in annoyance. For ambient noise level, the value of -1.0 indicates that each one unit (1.0 dB) increase in ambient L_{eq} level decreases annoyance by an amount equivalent to 1.0 dB of aircraft noise. The last column indicates that a decrease in ambient L_{eq} from 67 to 46 dB (a range encompassing 90 percent of the data) has an effect on aircraft noise annoyance which is equivalent to a 21-dB increase in aircraft noise level.

If the -1.0 estimate is correct, it implies that outdoor ambient noise level has as much effect on aircraft noise annoyance as does the aircraft noise level itself. Though the effect is significant ($p < 0.05$), the standard error of 0.5 (in parentheses in the next to the last column) indicates that the -1.0 estimate is too imprecise to be very useful. (The 95-percent confidence interval for the -1.0 value is from -0.1 to -2.0.)

Some possible explanations for a spurious effect were tested. The quality of the ambient noise level recordings was carefully checked, and the sites were examined to determine whether the ambient noise levels could be correlated with any other site characteristics. The possibility of a strong nonlinear relationship was rejected on the basis of an examination of a plot of the residual annoyance scores against ambient noise level.

Reduced aircraft noise annoyance in high ambient noise environments is consistent with several aircraft noise rating experiments in laboratory settings (refs. 6 and 7). However, the ambient effect was much weaker in the laboratory setting. Similar ambient level effects have not been present in other field studies.

The evidence in this section is consistent with an ambient level effect. This supports the theory that reduced ambient noise levels in evening or nighttime hours could create greater annoyance or other negative reactions and thus explain differing reactions at different times of day.

<u>Time of day of rating sessions</u>.- Aircraft noise rating sessions were equally divided among three time periods: morning, afternoon, and evening. The study design made it possible to control for ambient noise levels. As a result the between-period comparisons address the potential methodological problem of whether ratings might be affected by the time of day during which rating sessions are held. These comparisons do not address the potential effect of differing activity patterns at different times of day.

The graph of the reactions at different times of day in figure 9 suggests a time-of-day effect, but a regression analysis found that the effect is not statistically significant. (On the average, in comparison with afternoon reactions, the morning reactions were the equivalent of 4 dB more annoying, and evening ratings were the equivalent of 10 dB more annoying.) Similar estimates were obtained when ambient noise level was directly included in a multiple regression equation with the time period.

Aircraft Characteristics

Several different types of aircraft and aircraft operations could be studied with the ratings made by the participants in the study. Although the participants were unable to observe the aircraft visually, it is likely that, as residents of this airport community, they were able to use acoustical cues to distinguish among types of aircraft and operations.

Effects of type of operation (take-off or landing) were examined (figure 10 and table II). Any differences in reactions were not found to be statistically significant at the $p < 0.05$ level.

The reactions to different aircraft types, after controlling for noise level, are given in table III in terms of both the deviations from mean annoyance ratings and the decibel equivalent of these deviations. The overall contrast between propeller aircraft and jet aircraft is statistically significant at the $p = 0.05$

level. The differences between reactions to nine individual aircraft types in table III are equally large, but with the small numbers of ratings, the differences are not statistically significant. Figure 11 displays graphically the contrasting reactions to propeller and jet aircraft. In table IV there is no evidence that the use of a noise metric other than uncorrected L_A would reduce the effect of aircraft type. The slopes of the dose-response relationships for the two aircraft types are not significantly different ($p > 0.05$).

Though a lesser reaction to propeller aircraft is consistent with results from laboratory work (ref. 8), the field study estimate of 12 to 15 dB is greater than the laboratory study estimate of about 4 to 7 dB. The large discrepancy in the size of the propeller effect estimated in the laboratory and field studies could easily be due to the imprecision of the field estimates as indicated by the standard errors in table IV. Differences in reactions could also derive from differences between laboratory and field settings. In the field setting, participants may well have been more aware of other characteristics of the propeller aircraft such as their small size and use in general aviation as opposed to commercial operations. Thus the difference in field reactions might also be due to attitudes toward the noise source as well as to differences in the acoustical characteristics. A major advantage of the methodology used in this study is the ability to examine reactions when nonacoustical attributes are associated with acoustical events.

It should also be noted that at Salt Lake City the two types of aircraft are combined in a single environment. The airport is probably regarded as mainly a commercial airport by residents. It is not possible from the present evidence to determine whether the lessened reactions to general aviation (propeller) aircraft would be found around a predominantly general aviation airport where there are many training flights on established circuits and where the residents might have different attitudes towards the importance of recreational flying.

Personal Characteristics

The estimated effects of six personal characteristics are presented graphically in figures 12 to 17. The multiple regression analyses in table II show that estimates of the variables are very imprecise. Only the effect of age is statistically significant ($p < 0.05$ level). The age effect is reduced but still statistically significant when it is controlled for two correlated variables, hearing loss and length of residence, in a multiple regression analysis.

ASSESSMENT OF METHODOLOGY

In-home, field ratings are not often used in noise annoyance studies. Thus one objective of this study was to assess the methodology. This assessment will consider the effect of study design variables and the precision of the study estimates.

Effect of Study Design Variables

Laboratory studies often discard ratings made during a short practice period before the main test. For this study, all ratings were retained. In this study there is a moderate sized, but not significant, tendency ($p = 0.11$) for annoyance scores to increase by the equivalent of 0.8 dB for each additional flight. The apparently shallower slope for the first flight in figure 18 steepens and closely parallels the slopes for the rest of the flights when aircraft type is also included in the multiple regression analysis. Consideration of the order of the judgments does not affect the study conclusions presented above.

Respondents' ratings were made indoors, but as is standard in field surveys, the noise measurements used in the analysis were made outdoors. The indoor measurements, which were described earlier, were found to include too much internally generated noise to be reliable indicators of indoor aircraft noise levels. After considering the study procedures, it has been concluded that the most promising method for estimating indoor levels for in-house rating sessions would be to adjust the outdoor measured levels for the known noise-reduction characteristics of the structure. The noise reduction would, however, have to be measured when no people were in the house.

Inasmuch as differences between noise-reduction characteristics of houses have affected the study results, the effect will be to underestimate somewhat the effect of noise level on human response. The range of noise reduction afforded by houses with windows closed in cold climates is about 11 dB (from 23 to 34 dB(A) with a standard deviation of about 3 dB, ref. 9). With the large variance of the outdoor noise levels in this study ($\sigma^2 = 95$), a 3-dB standard deviation in house-attenuation values would introduce only about a 10-percent underestimate of the noise level partial regression coefficient or the squared multiple correlation coefficient (i.e., percent of variance explained by noise level).

Precision of Study Results and Individual Consistency

In table II it was seen that though personal, aircraft, or community variables are often related to annoyance, the estimates of the relationships are quite imprecise. The 95-percent confidence intervals are the equivalent of at least ±8 dB for aircraft type, operation type, daytime location, and home ownership. Much more precise estimates are clearly desirable.

More precise estimates are commonly obtained in laboratory studies. One such study (ref. 8), has been reanalyzed for comparison with the Salt Lake City in-home survey. The 2 to 4 times greater precision of the laboratory study results is obvious from comparisons of the standard errors σ_{B_L}, σ_{B_p}, and $\sigma_{(B_p/B_L)}$ of the regression coefficients in table V. Several explanations for the relatively low precision of the in-home study results have been considered.

The designs of the two studies are compared in several important respects in part A of table V. The in-home study design is superior in three respects: more study groups (sites or sessions), more subjects, and a greater range in noise levels. The laboratory study design is superior in two very critical aspects: the total number of ratings (6 times as many) and the very low correlation between noise level and aircraft type. The high correlation in the in-home study (r = 0.58) is one factor which contributes to the large standard error of the decibel equivalent of the propeller/jet difference $\left(\sigma_{(B_p/B_L)}\right.$ in part B of table V$\left.\right)$.

Given the contrast between the community setting and the laboratory setting, it might be expected that the more emotionally detached laboratory subjects would perform better and exhibit less variation in their ratings. However, in the last two lines of table V, it is seen that it is the laboratory study subjects who exhibit the greater subject-to-subject and flight-to-flight rating inconsistency. Since the laboratory study annoyance scale was slightly longer (11 points rather than the

9 points used in the in-home study; see part A of table V), part of the difference in the standard deviations may be due to the scale scoring. Under the assumption that respondents would be equally likely to fill up both scales (i.e., in-home standard deviation should be multiplied by 11/9, or 1.22), the subjects' differences would still be greater in the laboratory, though the flight-to-flight differences would be eliminated. The analysis thus shows that subjects give equal or more consistent ratings in the in-home study than they do in the laboratory.

One pattern in the residual annoyance scores does help to explain the different accuracies of the two studies; the ratings (even after being controlled for noise level) vary greatly from house to house in the Salt Lake City study ("group differences" in table V). This variation sharply contrasts with results from the laboratory study sessions, where as shown in the first line in part C of table V, the standard deviation of the laboratory study group effect is one-fourth that of the field study. The most likely but untested explanations for the in-home group effect are that similar responses were caused by (1) visual or spoken interaction between participants during the test session, (2) social interaction between the previously acquainted participants preceding the test, and (3) similarities in personal characteristics of participants, including relatives, at particular sites. Separate analyses found that the group differences could not be explained by the effects of the test administration team, ambient noise levels at sites, differing proportions of propeller and jet aircraft, or house-attenuation differences arising from the use of outdoor measurements for indoor ratings.

Another large difference between the performances of the laboratory and in-home subjects is the rate at which annoyance increases with noise level. The slope of the laboratory regression line ($B_L = 0.23$ in part B of table V) is almost 3 times as steep as that of the in-home study regression line. A substantial difference persists even when the effect of the correlation between subject and noise level in the in-home study is removed ($B_L = 0.13$ in footnote b of table V). This does not affect the standard errors of the noise level regression coefficient $\left(\sigma_{B_L}\right)$, but it does contribute to the imprecision in the estimates of the ratios of the regression coefficients (e.g., the value of $\sigma_{(B_p/B_L)} = 7$ for the decibel equivalent of the propeller/jet differences in table V).

The differences in the slopes and predicted values suggest that while the subjects in the laboratory tend to utilize a large portion of the scale for their ratings, the in-home subjects confine their ratings to the lower annoyance levels. The in-home subjects may be using the scale in an absolute sense (i.e., they are not actually annoyed by aircraft). Another possibility is that the in-home subjects are reserving their greatest relative annoyance ratings for either higher noise levels than were experienced during the rating period or for instances when the aircraft seem more annoying (e.g., when a valued activity is interrupted).

The precision of any future studies could clearly be increased if more flights were rated by each individual. Careful attention to the expected correlation between independent variables is also needed. The solution to the large study-site effect is not clear. Three procedures which might decrease site effects would be to (1) not include subjects who live in the same household, (2) have the experimenter rather than the houseowner select subjects (the houseowner is more likely to select only well-known friends), and (3) restrict between-subject interaction during the rating session.

CONCLUSIONS

None of the other metrics commonly used for assessing aircraft noise performed significantly better than A-weighted sound pressure level. The addition of duration or tone corrections yielded no improvement.

A significant difference was found between the ratings of commercial jet aircraft and general aviation propeller aircraft, with the latter being judged less annoying, regardless of the noise metric used. No significant differences were found between the ratings of landings and take-offs after controlling for noise level.

Aircraft noise annoyance reactions are stronger under low outdoor ambient noise conditions than under high outdoor ambient noise conditions. This relationship is consistent with the theory that reduced nighttime and evening ambient levels may result in more negative reactions to aircraft noise at night than during the day. After controlling for ambient noise in a multiple regression analysis, no significant differences were found between the ratings of single events obtained during the three time periods: morning, afternoon, and evening.

Several analyses compared the precision of the results of this study with those from a laboratory study which examined annoyance to propeller and jet aircraft. Subjects in the homes were at least as consistent in rating aircraft noise as were subjects in the laboratory. However, the laboratory study estimates were more precise. A major source of variability present in the in-home sessions but not in the laboratory study is attributable to differences between the houses and/or groups of participants in the in-home study.

The in-home rating technique used in this study is most suitable for examining reactions to noise when residents may associate important nonacoustical attributes (e.g., type of aircraft or flight maneuver) with the acoustical events. For the potential of the study method to be reached in the future, the precision must be increased by ensuring that more aircraft flyovers are rated by each participant, that the major independent variables in the study are not highly correlated with each other, and that the study-site effect can be reduced.

Langley Research Center
National Aeronautics and Space Administration
Hampton, VA 23665
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APPENDIX A

CONSENT FORM

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER

Experimental Consent Form

I understand that I will be asked questions and participate in experiments about the effects of aircraft noise on people. I understand that I may withdraw from these experiments at any time by a simple request to the investigators. I understand that although my name is recorded on the form, my name will be separated (permanently after 3 months) from the answers to insure complete confidentiality.

Information for residents:

General: The primary purpose for this investigation is to define a precise relationship(s) between subjective response and physical noise of an airport community. This information will lead to programs to optimize the reduction of aircraft noise through aircraft-airport operations, land-use planning, and aircraft design.

Routine statistical use of information:

Court proceedings.- In the event there is a pending court of formal administration proceedings, information may be disclosed to the Department of Justice or other agency for purposes of representing the Government, or in the course of presenting evidence, or they may be provided to parties or counsel involved in the proceeding in the course of pretrial discovery.

Other sources.- Information of this study will be disclosed to other individuals or organizations, including federal, state, or local agencies and nonprofit educational or private entities, who are participating in NASA programs or are otherwise furthering the understanding or application of the data. However, complete confidentiality of data sources is assured.

____
(Signature)

____
(Date)

APPENDIX B

INSTRUCTIONS FOR USE OF RESPONSE PANEL

ANNOYANCE EVALUATION INSTRUCTIONS (SINGLE)

I would now like you to evaluate the amount of annoyance you associate with aircraft noises. The amount of annoyance should reflect your reaction to the noise at this time. At the end of an aircraft noise, you can evaluate the annoyance of the noise with your hand-held response panel. You push one button to indicate your annoyance for each aircraft noise.

- Buttons are labeled "0" through "8."
- Push the "0" button if you are not annoyed at all.
- Push the "8" button if you are extremely annoyed.
- Push buttons between "0" and "8" to indicate amounts of annoyance between these two extremes.
- NOTE: Push the "0" button when you hear an aircraft noise, even if you are not annoyed.
- Each time a button is pushed, the number you pushed will appear in the upper panel window.

Before we start the test, push a couple of buttons for practice. Notice that you have to wait a couple of seconds before pushing the button for another aircraft.

ARE THERE ANY QUESTIONS?

APPENDIX C

QUESTIONNAIRE ADMINISTERED AFTER THE RATING SESSION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
COMMUNITY NOISE SURVEY

This information collection is authorized by the Federal Aviation Act of 1958, Section 311. Your participation in this survey is entirely voluntary. However, your cooperation is very important because your opinion will represent thousands of other households in this area.

1. Age ____________   2. MALE ☐   FEMALE ☐

3. What is your current home address: (Do not show house number)

____
Street
____
City   State   Zip Code

4. Does the head of your household: (Check √)

OWN ________   RENT ________

5. Compared to when you first moved into this home (for example, first month), has your annoyance to aircraft noise: (Check √)

Increased? __________
Decreased? __________
Remained the same? __________
Don't know __________

6. How many **miles** (approximately) do you travel to work: ______________

7. How many airplanes do you hear at work on a typical day? (Check √)(Check not appropriate if you do not work away from home.)

None __________
1 to 4 noises __________
5 to 10 noises __________
Greater than 10 __________
Not appropriate __________

8. How many years have you lived at your current address? ______________

If less than 10 years, go to question 9.

If more than 10 years, skip to question 12.

9. What was your previous address: (Do not show house number)

____
Street
____
City   State   Zip Code

10. How many years did you live at your previous address? ______________

11. Was your previous address within 10 miles of an airport? (Check √)

Yes ________   No __________

12. Do you or a member of your household **now** work for: (Check √, one or more)

An airport ______
Military aviation ______
An airline company ______
Other aviation related job ______
An aviation industry ______
None of the above ______

13. In the past, did you or a member of your household work for: (Check √, one or more)

An airport ______
Military aviation ______
An airline company ______
Other aviation related job ______
An aviation industry ______
None of the above ______

14. Do you or a member of your household have a pilot's license? (Check √)

Yes ________ No __________

15. Indicate your annoyance to commercial jet noise (**Circle**).

NOT ANNOYED AT ALL	0	1	2	3	4	5	6	7	8	EXTREMELY ANNOYED

16. Indicate your annoyance to helicopter noise (**Circle**).

NOT ANNOYED AT ALL	0	1	2	3	4	5	6	7	8	EXTREMELY ANNOYED

17. Indicate your annoyance to small, propeller-driven airplane noise (**Circle**).

NOT ANNOYED AT ALL	0	1	2	3	4	5	6	7	8	EXTREMELY ANNOYED

18. Indicate your **overall annoyance** to airplane noise of your neighborhood (**Circle**).

NOT ANNOYED AT ALL	0	1	2	3	4	5	6	7	8	EXTREMELY ANNOYED

19. Indicate the days of the week that you **routinely** spend away from home or work away from home (**Circle**).

None Mon Tues Wed Thurs Fri Sat Sun

If you circle **none** – skip to question 22

If you circle any days of the week – continue with question 20

20. For the days of the week you **routinely** spend **away from home**, or work away from home, indicate the following with a checkmark (√):

	TIME OF DAY	AT HOME	NOT AT HOME	TIME OF DAY	SLEEPING	NOT SLEEPING
MORNING	7 a.m.			7 a.m.		
	8 a.m.			8 a.m.		
	9 a.m.			9 a.m.		
	10 a.m.			10 a.m.		
	11 a.m.			11 a.m.		
	12 noon			12 noon		
AFTERNOON	1 p.m.			1 p.m.		
	2 p.m.			2 p.m.		
	3 p.m.			3 p.m.		
	4 p.m.			4 p.m.		
	5 p.m.			5 p.m.		
	6 p.m.			6 p.m.		
EVENING	7 p.m.			7 p.m.		
	8 p.m.			8 p.m.		
	9 p.m.			9 p.m.		
	10 p.m.			10 p.m.		
	11 p.m.			11 p.m.		
	12 p.m.			12 p.m.		
LATE NIGHT	1 a.m.			1 a.m.		
	2 a.m.			2 a.m.		
	3 a.m.			3 a.m.		
	4 a.m.			4 a.m.		
	5 a.m.			5 a.m.		
	6 a.m.			6 a.m.		

21. For the days of the week you **routinely** spend **away from home**, or work away from home, indicate your annoyance to aircraft noise at different times of the day (Circle number).

		NOT ANNOYED AT ALL								EXTREMELY ANNOYED
MORNING	7 a.m.	0	1	2	3	4	5	6	7	8
	8 a.m.	0	1	2	3	4	5	6	7	8
	9 a.m.	0	1	2	3	4	5	6	7	8
	10 a.m.	0	1	2	3	4	5	6	7	8
	11 a.m.	0	1	2	3	4	5	6	7	8
	12 noon	0	1	2	3	4	5	6	7	8
AFTERNOON	1 p.m.	0	1	2	3	4	5	6	7	8
	2 p.m.	0	1	2	3	4	5	6	7	8
	3 p.m.	0	1	2	3	4	5	6	7	8
	4 p.m.	0	1	2	3	4	5	6	7	8
	5 p.m.	0	1	2	3	4	5	6	7	8
	6 p.m.	0	1	2	3	4	5	6	7	8
EVENING	7 p.m.	0	1	2	3	4	5	6	7	8
	8 p.m.	0	1	2	3	4	5	6	7	8
	9 p.m.	0	1	2	3	4	5	6	7	8
	10 p.m.	0	1	2	3	4	5	6	7	8
	11 p.m.	0	1	2	3	4	5	6	7	8
	12 p.m.	0	1	2	3	4	5	6	7	8
LATE NIGHT	1 a.m.	0	1	2	3	4	5	6	7	8
	2 a.m.	0	1	2	3	4	5	6	7	8
	3 a.m.	0	1	2	3	4	5	6	7	8
	4 a.m.	0	1	2	3	4	5	6	7	8
	5 a.m.	0	1	2	3	4	5	6	7	8
	6 a.m.	0	1	2	3	4	5	6	7	8

APPENDIX C

22. For the days of the week you **routinely** spend **at home**, indicate the following with a checkmark (√):

	TIME OF DAY	AT HOME	NOT AT HOME	TIME OF DAY	SLEEPING	NOT SLEEPING
MORNING	7 a.m.			7 a.m.		
	8 a.m.			8 a.m.		
	9 a.m.			9 a.m.		
	10 a.m.			10 a.m.		
	11 a.m.			11 a.m.		
	12 noon			12 noon		
AFTERNOON	1 p.m.			1 p.m.		
	2 p.m.			2 p.m.		
	3 p.m.			3 p.m.		
	4 p.m.			4 p.m.		
	5 p.m.			5 p.m.		
	6 p.m.			6 p.m.		
EVENING	7 p.m.			7 p.m.		
	8 p.m.			8 p.m.		
	9 p.m.			9 p.m.		
	10 p.m.			10 p.m.		
	11 p.m.			11 p.m.		
	12 p.m.			12 p.m.		
LATE NIGHT	1 a.m.			1 a.m.		
	2 a.m.			2 a.m.		
	3 a.m.			3 a.m.		
	4 a.m.			4 a.m.		
	5 a.m.			5 a.m.		
	6 a.m.			6 a.m.		

23. For the days of the week you **routinely** spend **at home**, indicate your annoyance to aircraft noise at different times of the day (Circle number).

		NOT ANNOYED AT ALL								EXTREMELY ANNOYED
MORNING	7 a.m.	0	1	2	3	4	5	6	7	8
	8 a.m.	0	1	2	3	4	5	6	7	8
	9 a.m.	0	1	2	3	4	5	6	7	8
	10 a.m.	0	1	2	3	4	5	6	7	8
	11 a.m.	0	1	2	3	4	5	6	7	8
	12 noon	0	1	2	3	4	5	6	7	8
AFTERNOON	1 p.m.	0	1	2	3	4	5	6	7	8
	2 p.m.	0	1	2	3	4	5	6	7	8
	3 p.m.	0	1	2	3	4	5	6	7	8
	4 p.m.	0	1	2	3	4	5	6	7	8
	5 p.m.	0	1	2	3	4	5	6	7	8
	6 p.m.	0	1	2	3	4	5	6	7	8
EVENING	7 p.m.	0	1	2	3	4	5	6	7	8
	8 p.m.	0	1	2	3	4	5	6	7	8
	9 p.m.	0	1	2	3	4	5	6	7	8
	10 p.m.	0	1	2	3	4	5	6	7	8
	11 p.m.	0	1	2	3	4	5	6	7	8
	12 p.m.	0	1	2	3	4	5	6	7	8
LATE NIGHT	1 a.m.	0	1	2	3	4	5	6	7	8
	2 a.m.	0	1	2	3	4	5	6	7	8
	3 a.m.	0	1	2	3	4	5	6	7	8
	4 a.m.	0	1	2	3	4	5	6	7	8
	5 a.m.	0	1	2	3	4	5	6	7	8
	6 a.m.	0	1	2	3	4	5	6	7	8

APPENDIX D

SUPPORTING DATA

TABLE DI.- NUMBER OF RATINGS IN EACH NOISE AND ANNOYANCE CATEGORY

Rating on annoyance scale	Number of responses for peak noise level, dB(A), of				
	43-49	50-54	55-59	60-64	65-73
8	16	4	12	0	0
7	14	18	20	1	9
6	27	18	29	8	10
5	25	17	19	10	8
4	35	25	47	40	12
3	28	39	32	53	14
2	20	59	46	40	25
1	19	45	33	30	33
0	39	59	49	42	35
Total	223	284	287	224	146

REFERENCES

1. Bennett, Ricarda L.; and Pearsons, Karl S.: Handbook of Aircraft Noise Metrics. NASA CR-3406, 1981.

2. Stevens, S. S.: Perceived Level of Noise by Mark VII and Decibels (E). J. Acoust. Soc. America, vol. 51, no. 2, pt. 2, Feb. 1972, pp. 575-601.

3. Stevens, S. S.: Procedure for Calculating Loudness: Mark VI. J. Acoust. Soc. America, vol. 33, no. 11, Nov. 1961, pp. 1577-1585.

4. Noise Standards: Aircraft Type and Airworthiness Certification. Federal Aviation Regulations, vol. III, pt. 36, FAA, 1978.

5. Kish, Leslie; and Frankel, Martin Richard: Inference from Complex Samples. J. R. Stat. Soc., vol. 36, no. 1, 1974, pp. 1-37.

6. Powell, C. A.; and Rice, C. G.: Judgments of Aircraft Noise in a Traffic Noise Background. J. Sound & Vib., vol. 38, no. 1, Jan. 8, 1975, pp. 39-50.

7. Powell, Clemans A.: Effects of Road-Traffic Background Noise on Judgments of Individual Airplane Noises. NASA TP-1433, 1979.

8. McCurdy, David A.; and Powell, Clemans A.: Annoyance Caused by Propeller Airplane Flyover Noise: Preliminary Results. NASA TM-83244, 1981.

9. House Noise-Reduction Measurements for Use in Studies of Aircraft Flyover Noise. AIR 1081, Soc. Automot. Eng., Inc., Oct. 1971.

TABLE I.- CORRELATION BETWEEN ANNOYANCE AND VARIOUS NOISE METRICS

Correction	Equation form	Multiple correlation coefficient for annoyance ratings and									
		SIL	SPL	L_A	L_B	L_C	L_D	PNL	PL	L_E	LL
None	Linear	0.422	0.363	0.419	0.385	0.363	0.407	0.405	0.405	0.406	0.406
	Quadratic	.422	.366	.419	.386	.366	.407	.405	.405	.406	.406
Tone	Linear		.353	.414	.377	.354	.401	.400	.399	.400	.399
	Quadratic		.354	.414	.377	.355	.401	.400	.399	.400	.399
Duration	Linear	.406	.350	.401	.374	.351	.395	.390	.381	.391	.377
	Quadratic	.407	.357	.401	.377	.358	.395	.390	.382	.391	.378

TABLE II.- EFFECTS OF COMMUNITY, AIRCRAFT, AND PERSONAL CHARACTERISTICS ON REACTIONS TO NOISE (MULTIPLE REGRESSION ANALYSIS)

Community, aircraft, or personal characteristic, v, and coding	90-percent range for v	Intercept	Partial regression coefficient, B, and (standard error, σ_B) for - (a): Aircraft noise level, B_L	Aircraft type: Miscellaneous, B_m	Aircraft type: Propeller, B_p	Characteristic (see column 1), B_v	Estimated decibel equivalent effect and (standard error) for - (a): Propeller, B_p/B_L	Characteristic (see column 1), B_v/B_L	90-percent range for characteristic v (see column 2)
Ambient noise L_{eq}	46-67 dB	1.16	0.08‡ (0.02)	-0.21 (0.87)	-1.00* (0.40)	-0.08† (0.03)	-13 (8)	-1.0 (0.5)	21
Operation type 1 = Landing 0 = Take-off	0-1	-3.78	0.08‡ (0.02)	-0.08 (0.66)	-0.86† (0.33)	0.23 (0.59)	-11 (5)	3 (7)	3
Daytime location 0 = At home 1 = Not home	0-1	-3.24	0.08‡ (0.02)	-0.16 (0.61)	-0.91* (0.37)	-0.55 (0.38)	-12 (6)	-7 (5)	7
Length of residence	2-30 years	3.16	0.08‡ (0.02)	-0.09 (0.75)	-0.90* (0.39)	-0.02 (0.02)	-11 (7)	-0.2 (0.3)	7
Home ownership 1 = Own 0 = Rent	0-1	-3.15	0.08‡ (0.02)	-0.07 (0.74)	-0.89* (0.40)	-0.38 (0.48)	-11 (7)	-5 (6)	5
Age of respondent	20-60 years	-2.27	0.08‡ (0.02)	-0.07 (0.74)	-0.86* (0.37)	-0.02 (0.01)	-11 (6)	-0.3* (0.2)	13
Sex 0 = Female 1 = Male	0-1	-3.17	0.08‡ (0.02)	-0.16 (0.64)	-0.91* (0.38)	-0.16 (0.29)	-12 (7)	-2 (4)	2
Hearing loss[b]	3-52 dB	-3.43	0.08‡ (0.02)	0.04 (0.70)	-0.72* (0.34)	-0.02 (0.01)	-9 (5)	-0.2 (0.1)	11

[a]Statistical significance as follows:
*p = 0.05
†p = 0.01
‡p = 0.001
[b]Excludes 101 ratings by 12 people without audiograms.

TABLE III.- EFFECT OF TYPE OF AIRCRAFT ON ANNOYANCE

Type of aircraft	Deviations from predicted annoyance expressed in		Number of ratings
	Annoyance scores (a)	Decibel equivalent annoyance units (b)	
Jet			
B-707, KC-135, DC-8	1.4	18	39
B-727	.3	4	369
B-737	.1	2	298
DC-9	.1	-1	89
Light jets	-.2	-3	34
Propeller - general aviation			
One-engine propeller	-.8	-10	110
Two-engine propeller	-.8	-10	142
Miscellaneous			
Other flights (helicopter, military fighter jets, etc.)	.5	6	37
Ground operations	.4	-5	46

[a]Annoyance scores are calculated from a regression in which the aircraft types are represented by dummy variables and aircraft noises are measured as L_A. The annoyance scores are deviations above or below the average annoyance level regression line.

[b]The decibel equivalent annoyance units are calculated by dividing the annoyance score deviation in the first column by the partial regression coefficient for noise level ($B_L = 0.077$).

TABLE IV.- EFFECT OF AIRCRAFT TYPE FOR SIX METRICS

[Aircraft type definitions are given in table III. Since the jet aircraft are not represented with a dummy variable, the miscellaneous aircraft and propeller aircraft partial regression coefficients represent deviations from the jet aircraft]

Noise metric and correction	Intercept	Partial regression coefficient, B, and (standard error, σ_B) for (a)			Propeller estimated decibel equivalent effect, B_p/B_L (a)
		Aircraft noise level, B_L	Aircraft type: Miscellaneous, B_m	Aircraft type: Propeller, B_p	
L_A, uncorrected	-5.05	0.08[‡] (.02)	-0.15 (.64)	-0.91* (.38)	-12 (7)
L_A, duration corrected	-4.78	.07[†] (.02)	-.30 (.62)	-.98* (.45)	-13 (9)
L_A, tone corrected	-5.12	.07[‡] (.02)	-.16 (.63)	-.97* (.38)	-13 (7)
PNL, uncorrected	-5.85	.07[‡] (.02)	-.27 (.62)	-1.02[†] (.34)	-14* (7)
PNL, duration corrected	-5.70	.07[†] (.02)	-.41 (.69)	-1.07[†] (.41)	-15 (9)
PNL, tone corrected	-5.91	.07[‡] (.02)	-.28 (.61)	-1.08[†] (.34)	-15* (7)

[a]Statistical significance as follows:
*$p = 0.05$
†$p = 0.01$
‡$p = 0.001$

TABLE V.- COMPARISON OF THE IN-HOME STUDY (SALT LAKE CITY) AND A LABORATORY STUDY

Parameter	In-home study	Laboratory study
Part A: Study design		
Number of groups (sessions)	25	16
Number of subjects	100	64
Number of ratings	1164	6912
Average peak noise level, dB(A)	82 (outside home)	74 (in room)
Standard deviation of noise levels, dB(A)	9.8	8.2
Points on annoyance scale (range)	9 (0 to 8)	11 (0 to 10)
Labels for end points of scale	"Not annoyed at all" "Extremely annoyed"	"Not annoying at all" "Extremely annoying"
Correlation between noise level and aircraft type	0.58	0.07
Part B: Regression of annoyance on noise level and aircraft type[a]		
Intercept	-3.23	-12.83
Slope of aircraft noise level, B_L	0.08	0.23
Standard error, σ_{B_L}	(0.02)	(0.01)
Propeller/jet difference, B_p	-0.91	-1.50
Standard error, σ_{B_p}	(0.38)	(0.09)
Decibel equivalent of propeller/ jet difference, B_p/B_L	-12	-7
Standard error, $\sigma_{(B_p/B_L)}$	(7)	(2)
Part C: Variations in responses around regression line (standard deviation of residual)[b]		
Group (session) differences	1.15	0.28
Subject differences	1.02	1.59
Flight rating differences within individuals[c]	1.45	1.72

[a]For the in-home study, a third aircraft type (other) was included in the regression equation with a partial regression coefficient of B = -0.15.

[b]A maximum likelihood estimation technique was used to solve a regression equation in which groups and individuals were represented by dummy variables. The in-home study regression equation intercept is -7.83 with a slope of 0.13. The laboratory values are -12.86 and 0.23.

[c]The within individual residuals, like all other group and individual effects calculated here, use a single estimate of the regression slope for the whole sample.

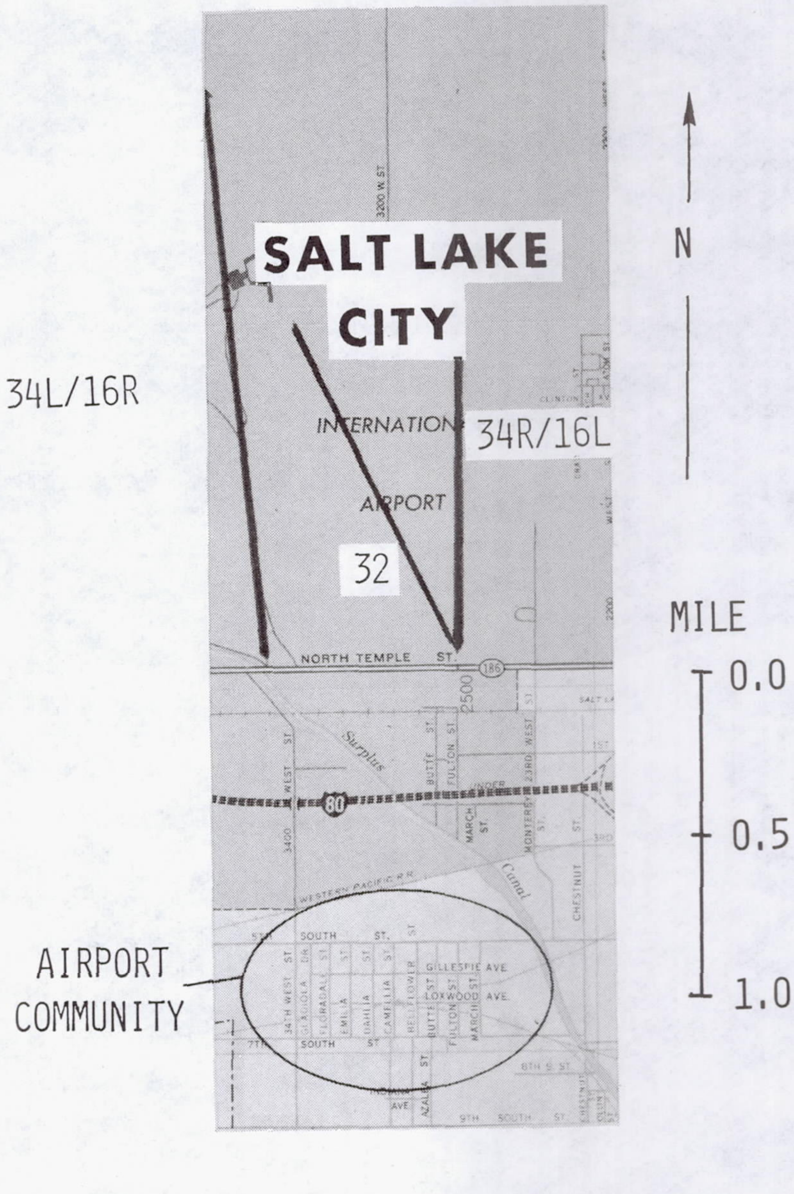
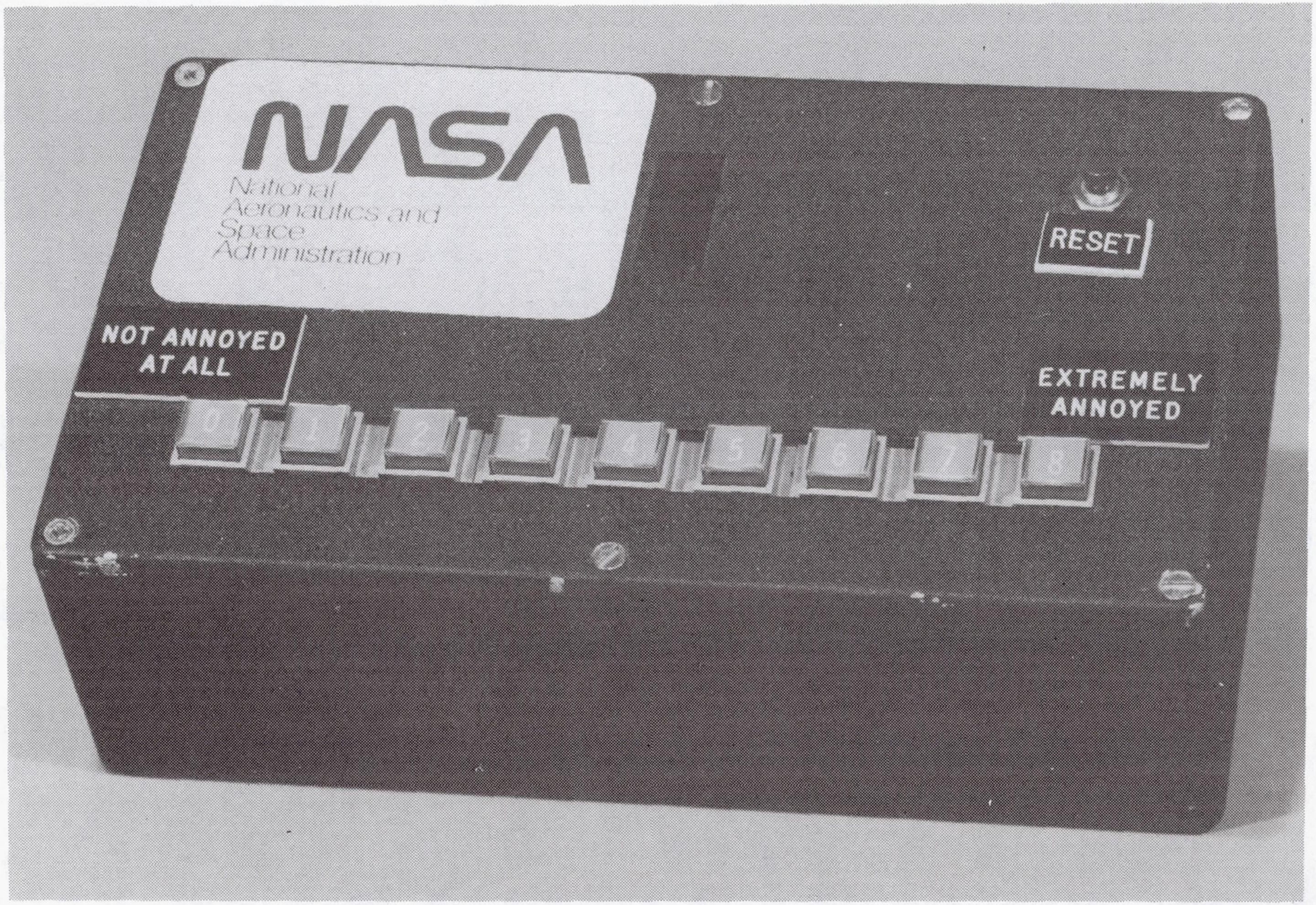


Figure 1.- Location of airport community.



L-81-7232

Figure 2.- Annoyance response panel.

L-80-10,141

Figure 3.- Outdoor aircraft noise measurement system.

L-81-1692

Figure 4.- Indoor aircraft noise measurement system.

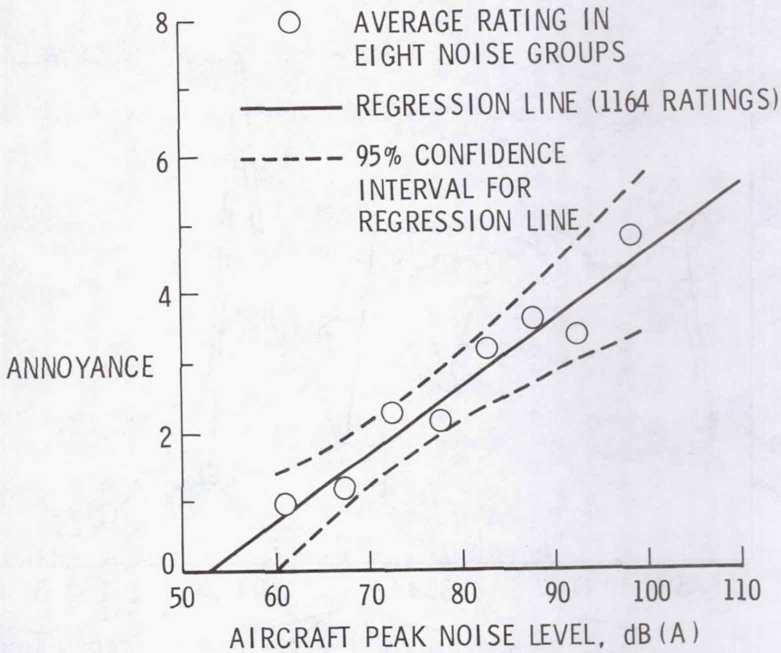


Figure 5.- Dose-response relationship for all ratings.

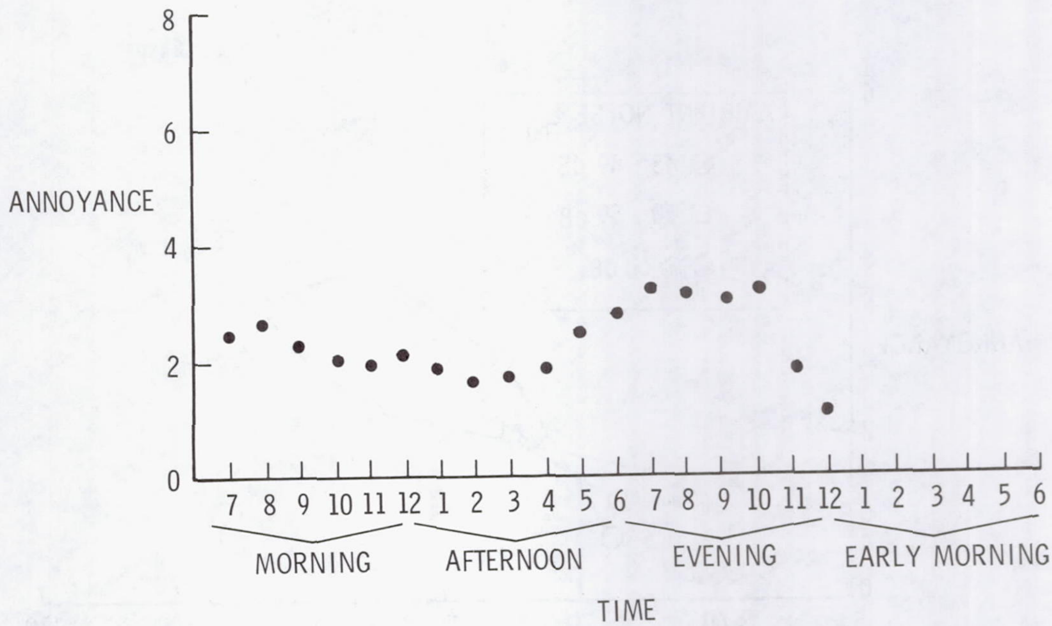


Figure 6.- Mean annoyance for each hour of the day. From questionnaires administered after rating session.

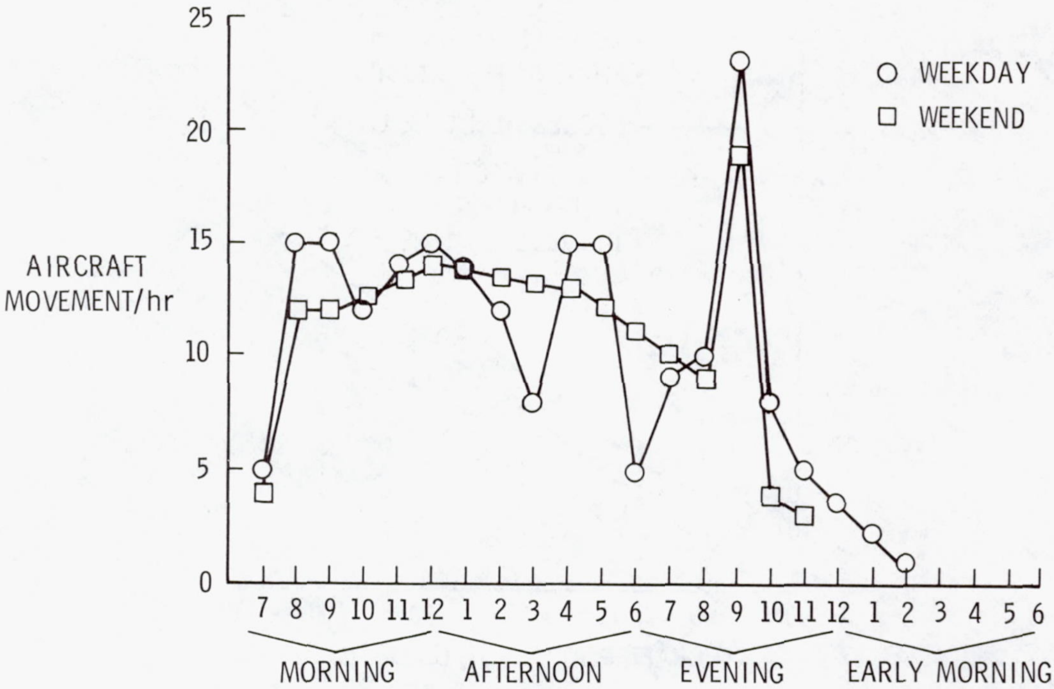


Figure 7.- Distribution of scheduled aircraft movements.

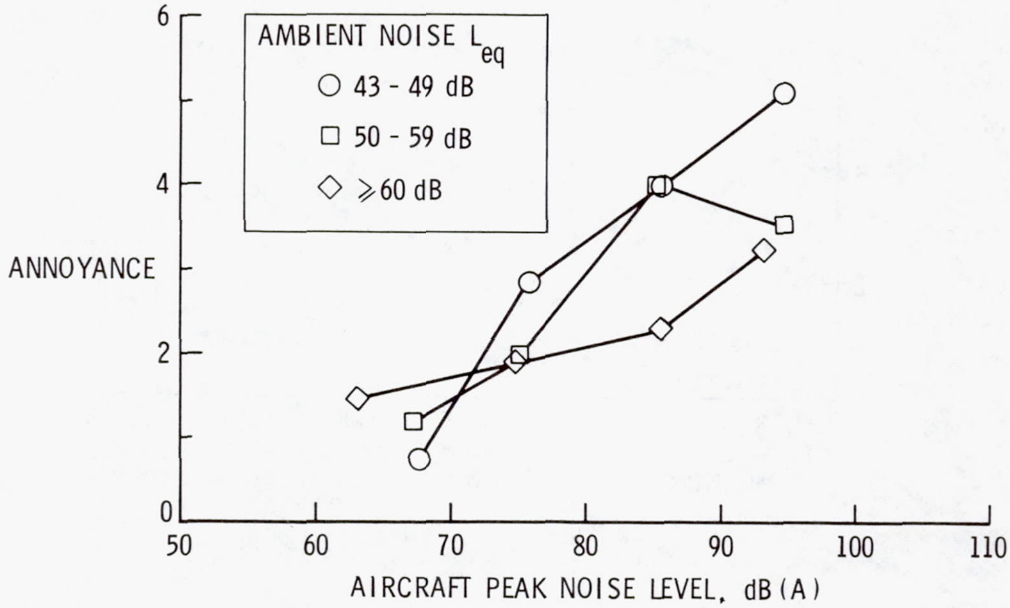


Figure 8.- Annoyance ratings within ambient noise categories.

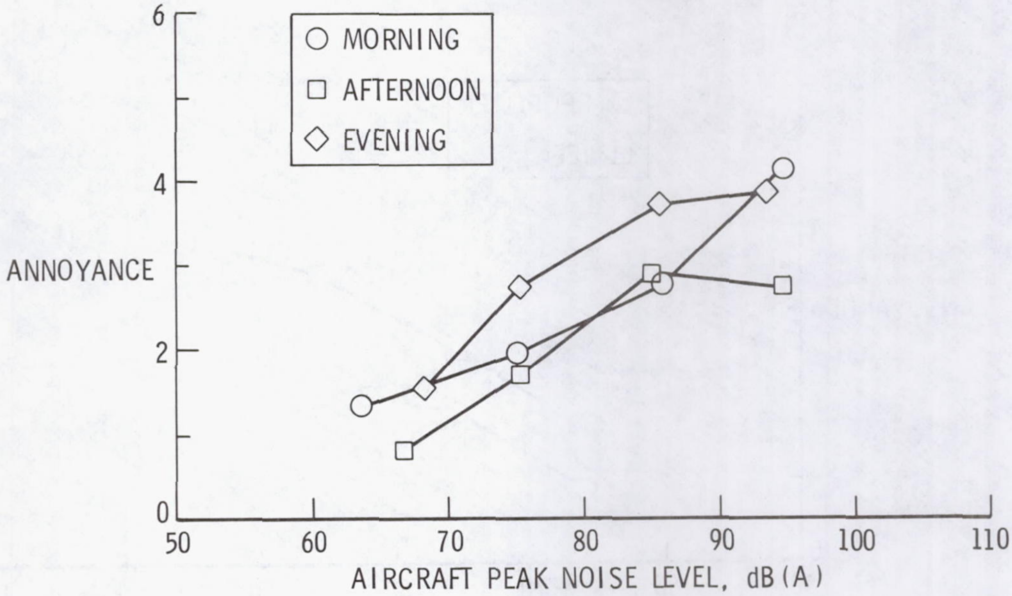


Figure 9.- Relationship between time of day of test session and annoyance.

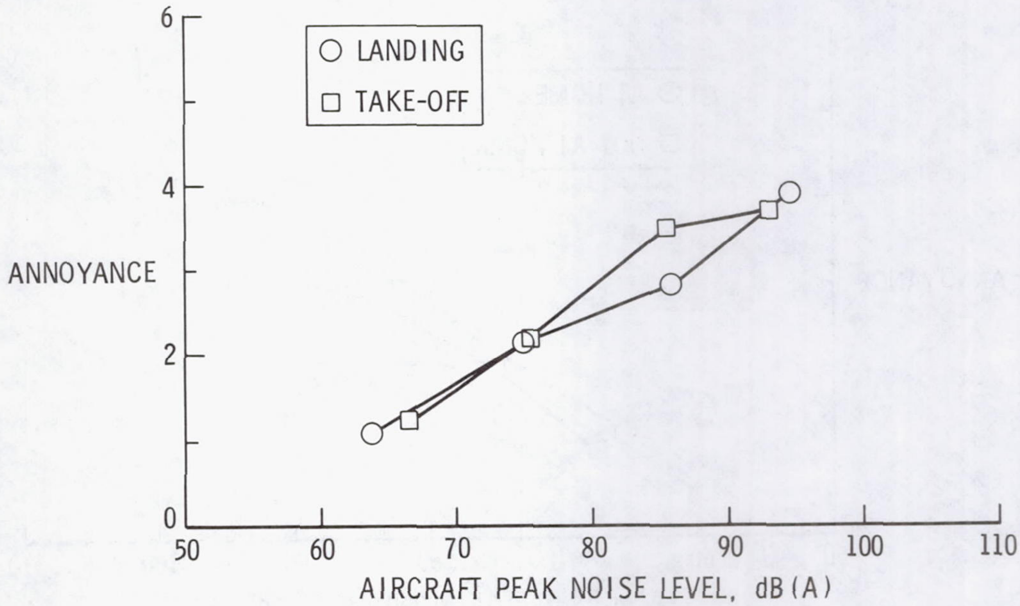


Figure 10.- Relationship between aircraft mode of operation and annoyance.

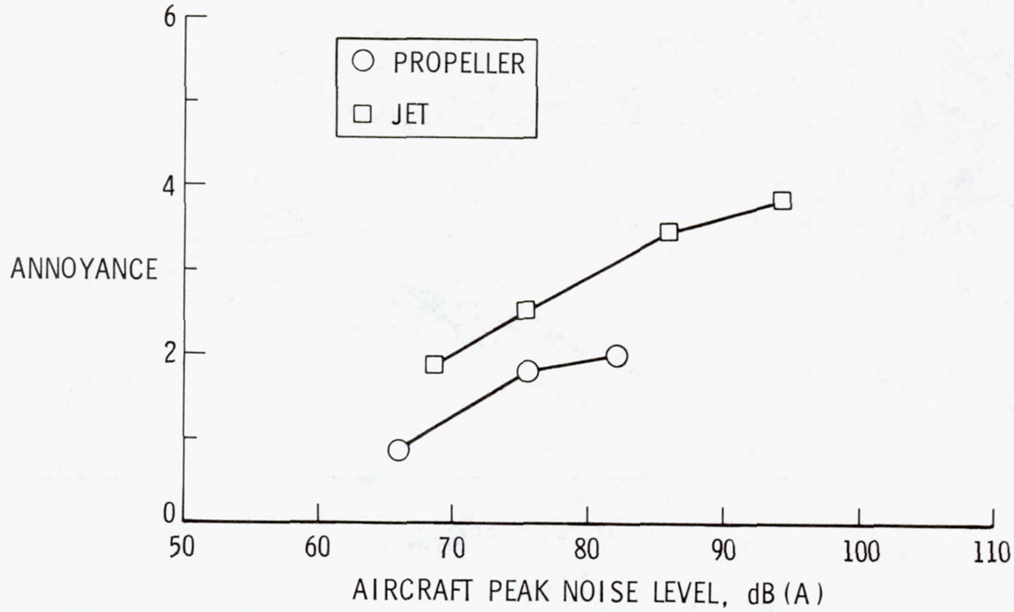


Figure 11.- Relationship between aircraft type and annoyance.

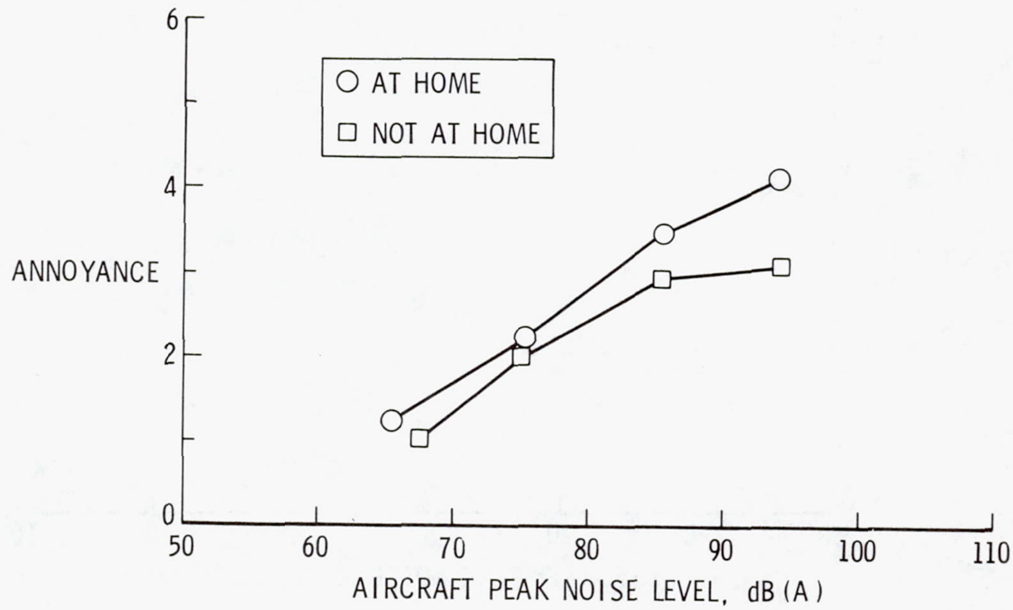


Figure 12.- Relationship between participants' usual location during the day and annoyance.

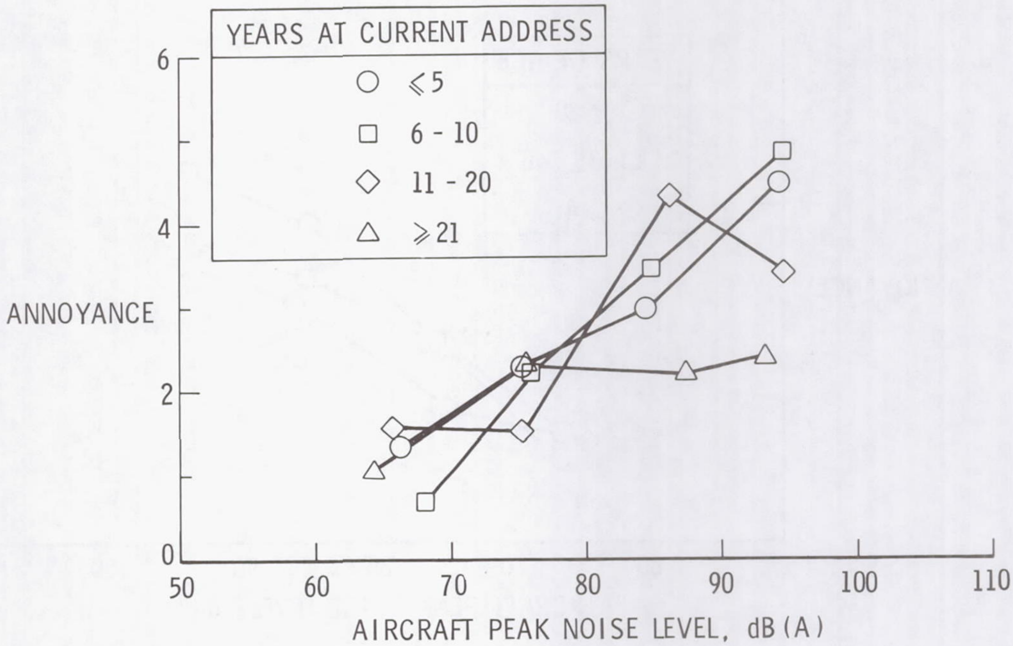


Figure 13.- Relationship between participants' length of residence and annoyance.

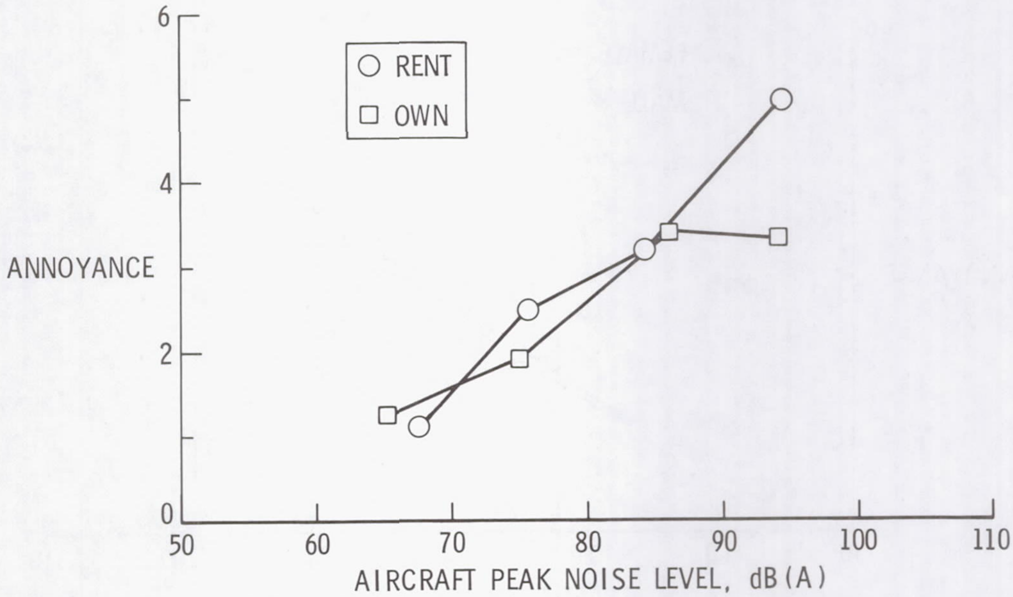


Figure 14.- Relationship between home ownership and annoyance.

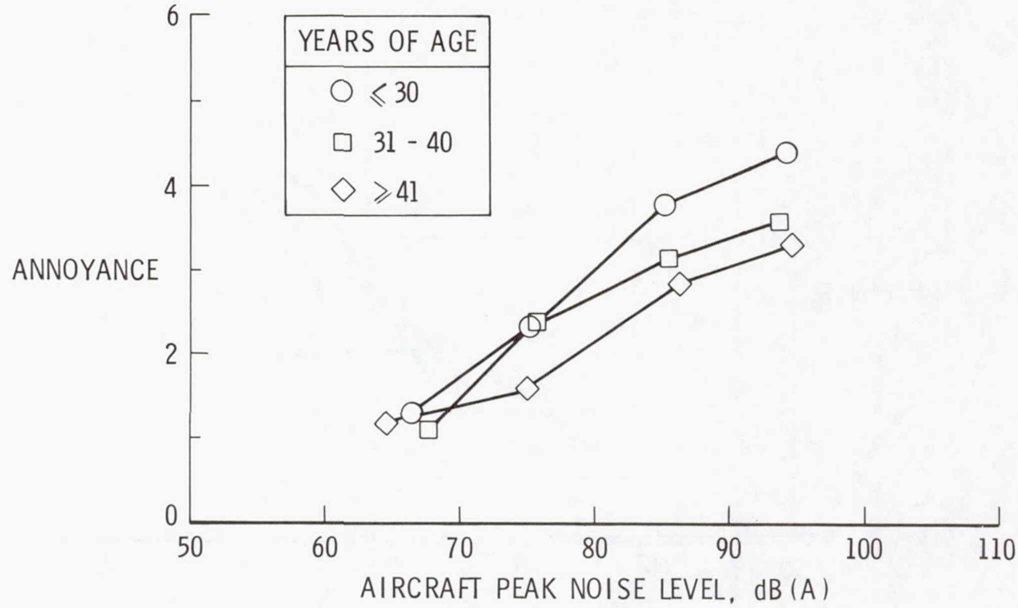


Figure 15.- Relationship between age of participants and annoyance.

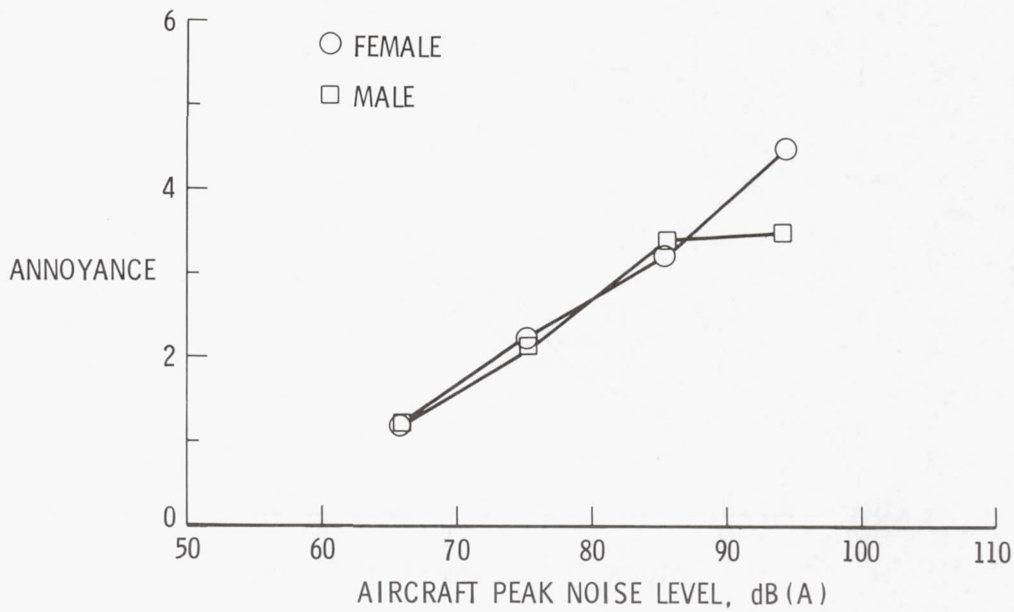


Figure 16.- Relationship between sex of participants and annoyance.

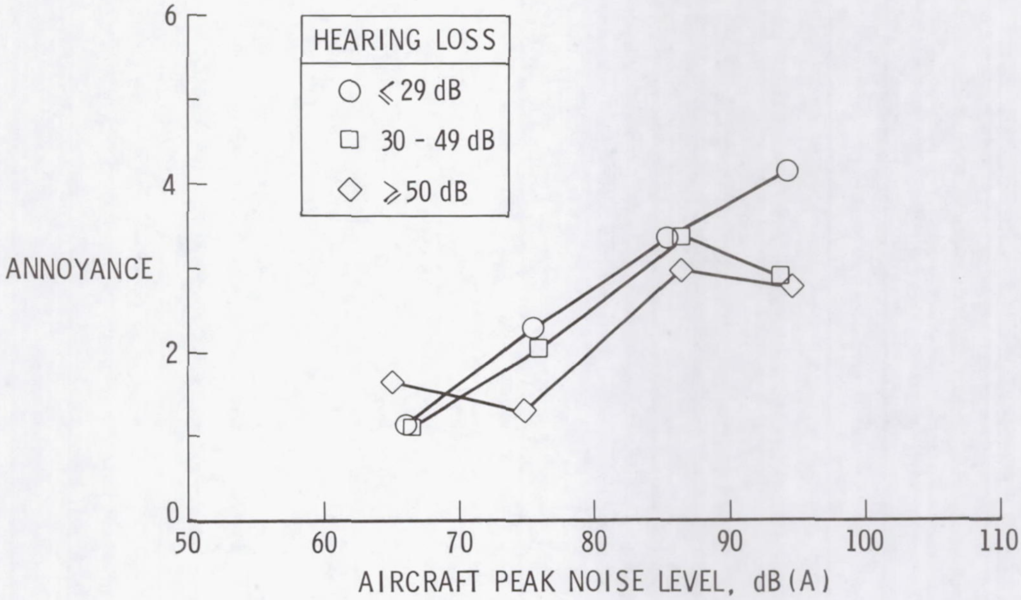


Figure 17.- Relationship between participants' hearing losses and annoyance.

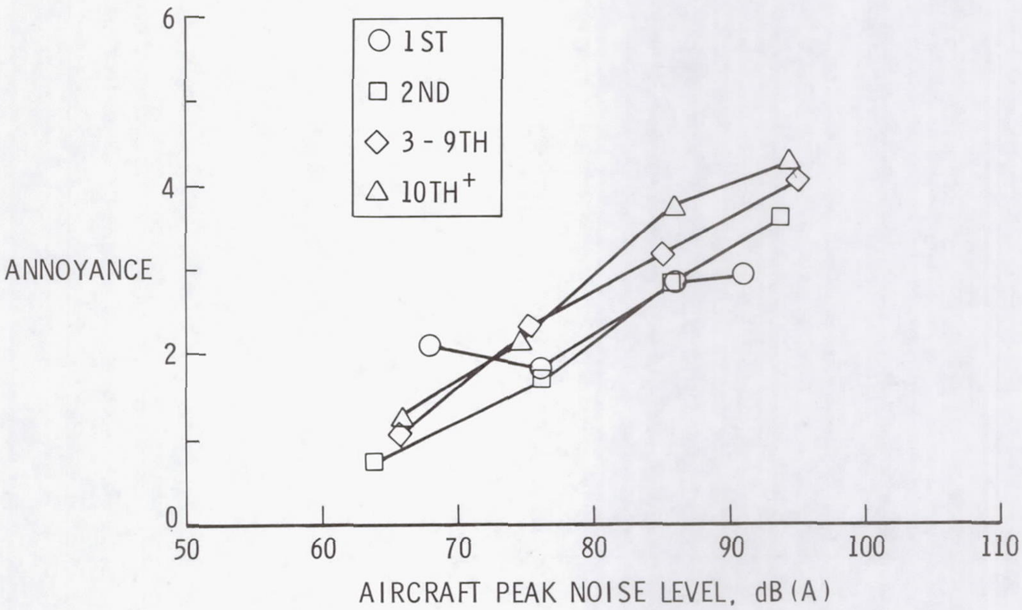


Figure 18.- Relationship between order of event within rating session and annoyance.

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15. Supplementary Notes

Thomas K. Dempsey and David G. Stephens: Langley Research Center, Hampton, Virginia.
James M. Fields and Kevin P. Shepherd: Bionetics Corporation, Hampton, Virginia.

16. Abstract

In a study conducted in the vicinity of Salt Lake City International Airport, community residents reported their annoyance with individual aircraft flyovers during rating sessions conducted in their homes. Annoyance ratings were obtained at different times of the day. Aircraft noise levels were measured, and other characteristics of the aircraft were noted by trained observers. Metrics commonly used for assessing aircraft noise were compared, but none performed significantly better than A-weighted sound pressure level. A significant difference was found between the ratings of commercial jet aircraft and general aviation propeller aircraft, with the latter being judged less annoying. After the effects of noise level were accounted for, no significant differences were found between the ratings of landings and takeoffs. Aircraft noise annoyance reactions are stronger in lowered ambient noise conditions. This is consistent with the theory that reduced nighttime and evening ambient levels could create different reactions at different times of day. After controlling for ambient noise in a multiple regression analysis, no significant differences were found between the ratings of single events obtained during the three time periods: morning, afternoon, and evening.

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